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## PRE-CAMBRIAN IN OHIO.\*

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### INTRODUCTION.

This probably is the largest topic on our program, about as large a topic as one could select in Ohio. And yet, the subject contains about as little that is really known as any subject one could choose. The material presented here is a by-product of my work on the Physiography of Ohio, where a knowledge of the ancient physiographies of the state is not only interesting, but essential. In consultation with our State Geologist he gave permission to present it and even urged its publication before the bulletin shall be printed. Such a procedure has a double advantage. It brings whatever there is of value before us all some time before it can now possibly come out in the bulletin, and it gives us an opportunity to discuss the problems before publication in a more permanent form. The material to be examined divides easily into three parts which become the section headings used.

### PRE-CAMBRIAN SURFACE.

Essentially everywhere in Ohio where older sedimentary rocks are exposed, along the Cincinnati arch and particularly in southwestern Ohio, the rocks are in layers with very low angle dips often so nearly horizontal that without leveling instruments no dip can be detected for miles. Scores of wells in the southwestern quarter of Ohio reach the level of the Trenton beds, the lowest strata exposed in Ohio, and always they are reported present and thus shown to be essentially continuous and at similar depths. It is upon the Trenton

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that the Cincinnati anticline structure is best mapped. In the northwest quarter of the state hundreds of wells have been drilled to the Trenton and the continuity and general depth are found. This can mean at least one thing concerning the pre-Trenton surface, that it was not very rough but rather notably smooth and level when the Trenton materials began to accumulate. Some few wells in western Ohio go through the Trenton and the same simple structure and levelness of beds is also found below. The only departure is the broad, low arch of the Cincinnati anticline which is known to owe its origin to post-Trenton movements.

But in addition to these many wells which end in Trenton and in rare cases in Cambrian with a goodly number stopping in strata of lower Ordovician, we now have several wells that go through all sedimentary material into underlying metamorphics. Data pertinent to our study have been collected and will be stated here.\*

The first well to go through was at Findlay and was drilled in 1912.† It penetrated 210 feet into granitic gneiss after going through 2770 feet of sediments. The head of the well has an elevation of 830 feet. Hence the Pre-Cambrian surface at Findlay is 1940 feet below sea level. Two wells a few miles apart in different townships were drilled, but they gave essentially parallel records which are here treated as one well. Another well going through is at Woodville, about 30 miles northeast of Findlay. This one reached granitic gneiss at 2672 feet and penetrated 150 feet. The head of this well is 655 feet above sea level so the Pre-Cambrian surface at Woodville is 2017 feet below sea level. A third well located near Tiffin reached the granitic gneiss at 2950 feet. Since the well-head is at 760 feet above sea level, the Pre-Cambrian surface there is 2190 feet below sea level. The Tiffin well is 28 miles almost directly east of Findlay and 25 miles S. by S. E. from Woodville. These three occupy the corners of a triangle 25, 28 and 30 miles on a side.

Findlay and Woodville are almost on the Cincinnati anticline axis, and at these two places the Pre-Cambrian is nearly at the same altitude, 1940 and 2017 feet below sea level, a

\*Dr. Wilber Stout, State Geologist of Ohio; Dr. J. E. Carman, of Ohio State University, and Mrs. Theron Wasson, formerly with the Pure Oil Company, have assisted in bringing these data together. Specific reference to published data can be given for two or three wells.

†American Journal of Science, Vol. 35 (1913), pp. 124-130.

descent of 77 feet in 30 miles. The top of the Trenton descends 187 feet in the same distance. The Tiffin well is down the east slope of the anticline and the Pre-Cambrian surface is at 2190 feet below sea level which gives a descent down the anticline of 250 feet in 28 miles.

At New London, 43 miles east of Tiffin, hence farther down the east flank of the anticline, another well was drilled in 1925. This well reached the Trenton at 3645 feet and penetrated 756 feet of Trenton, but drillers believed they did not go quite through this formation. The well-head is at 991 feet above sea level, hence the top of Trenton is 2654 feet below sea level. Here we have a dip of the Trenton eastward from Findlay to New London of 2319 feet in 71 miles, or 32+ feet per mile. The Pre-Cambrian slope from Findlay to Tiffin is nearly 9 feet per mile, no doubt becoming steeper toward Tiffin. Other wells reaching the Trenton in this part of the state indicate its planeness and its even dip from the vicinity of Tiffin eastward. It may be fair to assume that the Pre-Cambrian follows the Trenton slope down eastward as closely as it follows in the three wells on the triangle. Certainly there is no evidence against this assumption. Such assumption would place the Pre-Cambrian surface at New London at 4259 feet below sea level.

These four wells have found no unevennesses in the Pre-Cambrian surface except those exactly correlated with the Cincinnati anticline. All wells that have stopped in the sediments from the Trenton down have failed to encounter any Pre-Cambrian elevations or thinning of the sedimentary strata as if lying over a Pre-Cambrian hill. This again suggests notable evenness of the Pre-Cambrian surface over this Findlay-Woodville-New London portion of the state.

At South Charleston, 84 miles almost directly south of Findlay and some miles down the east flank of the Cincinnati structure, is the Friend well drilled in 1926-7. The well-head is 1100 feet above sea level. The Trenton was reached at a depth of 1245 feet or 145 feet below sea level. Its thickness was 610 feet, about 120 feet less than in the Findlay region and about as much thinner as found at Waverly in a well to be discussed shortly. The Trenton is 190 feet higher here than at Findlay, an ascent of  $2\frac{1}{4}$  feet per mile, but it rises southward along the axis of the anticline faster than on this N-S line. Below the Trenton was found 800 feet of Ordovician,

665 feet of upper Cambrian and 99 feet of red clastic material, probably middle Cambrian. Thus these sediments continue downward 2319 feet below sea level. The drill next passed through 421 feet of material classed by those who studied it as Upper Keweenawan, and then through 807 feet of black carbonaceous limestones. If these 1228 feet are Pre-Cambrian, the surface we are describing is here about the same depth as at Tiffin—remarkably near the same. Even if all these 1228 feet are Cambrian, which seems a much more probable interpretation to one who has not seen them, and the Pre-Cambrian surface is not far below them, then our Pre-Cambrian surface is some 3547 feet, or a little more, below sea level. Such an interpretation is wholly consistent with the Paleogeographic maps which show the Cambrian seas spreading over Ohio from the south as early as Middle or possibly late Early Cambrian time.

On this more generous interpretation the Pre-Cambrian surface would be placed some 3600 feet below sea level at South Charleston, not as deep on this eastern flank by 600 feet as it surely is at New London. Nor is South Charleston as far down the flank. But with all this increase in depth from Findlay to South Charleston, 1600 feet in 84 miles, we here have only feeble relief, less than 20 feet per mile and much of this is to be accounted for by the position of the South Charleston well with reference to the Cincinnati arch.

For years the Waverly well\* drilled about 1910 was interpreted as having reached crystalline rocks called serpentines but in recent years there has been much doubt about this interpretation. In this well near Waverly the Trenton was 729 feet thick and was struck at a depth of 2100 feet. Since the altitude of the well-head is 600 feet, the Trenton was found at 1500 feet below sea level. From South Charleston to Waverly is 60 miles nearly directly down the east flank of the anticline. With the Trenton below sea level 145 feet at the former town and 1500 feet at the latter, the rock dips 22-3 feet per mile. With the Upper Keweenawan (Pre-Cambrian) at 2319 feet below sea level at South Charleston, and the structure descending 22 feet per mile as it does on the Trenton, the Pre-Cambrian could hardly be less than 3674 feet below sea level at Waverly. These so-called serpentine fragments were found at 2720 feet below sea level.

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\*American Journal of Science, Vol. 31 (1911), pp. 19 ff.

Again, if the so-called Upper Keweenawan and black carbonaceous limestones of South Charleston are also present at Waverly, as seems reasonable on the grounds of an invading Cambrian sea from the south, one could not expect to find Pre-Cambrian higher than 4183 feet below sea level. Thus it seems very probable that whatever the material is that has been called "serpentine fragments" it cannot be Pre-Cambrian. The Pre-Cambrian at Waverly probably will be found over 4000 feet below sea level.

By similar reasoning from the depth to Trenton in southern Ohio, the Pre-Cambrian would have been reached in the Iron-ton well at not less than 5250 feet below sea level, for the Trenton was found there at 2670 feet below tide.

Summarizing the above paragraphs, we have Pre-Cambrian known at Woodville at 2017 feet below sea level, at Findlay at 1940 feet, and at Tiffin at 2190 feet. Calculating its depth below the Trenton as great as it was found in the three wells New London may have Pre-Cambrian at 4259 feet below sea level. South Charleston has Pre-Cambrian at 2319 if the materials are truly diagnosed as Keweenawan, but a better interpretation seems to place the Pre-Cambrian a little lower than 3547 feet below sea level. These depths find no inequalities in the surface of the old rocks except such as are due to the up-warping of the broad geanticline. Hundreds of wells scattered over western Ohio reaching Trenton or deeper likewise find no other inequalities. Therefore it seems safe to assume that this Pre-Cambrian surface is very remarkably even and smooth with slopes of not more than 2-10 feet per mile except those down the flanks of the anticline. Such a surface across crystalline rocks can be none other than an erosion surface. To have been an erosion surface it must have been much higher than it is now and somewhat, though but little, above sea level. But to consist of such rocks as are found in it, there must once have been hundreds of feet of rock above this Pre-Cambrian surface. Hence, there must have been great Pre-Cambrian erosion to peneplanation in Ohio. Such an erosion surface has been widely recognized elsewhere and the time required to make it has been called the Lipalian interval.

Some support for this interpretation of the character of the Pre-Cambrian surface is found in a well which reaches granite at about 3000 feet below sea level at Amboy, Illinois.

Much more support comes from the gradual disappearance of a similar Pre-Cambrian surface exposed in Canada, Wisconsin, and Minnesota, but sloping down under late Cambrian sediments in Canada and in more southerly parts of these two states. With such gentle decline below younger rocks this surface would reach the depths where we find it in Ohio.

#### PRE-CAMBRIAN MATERIALS.

This section has much less to offer than the former. Only three wells in Ohio have positively reached the Pre-Cambrian. Each seems to have found red granitic gneiss. If the South Charleston well has reached it, the material is partly clastic, partly limestone, and the latter is not metamorphosed. Diabase dike in sediments and underlain by over 100 feet of Keweenaw is reported in the Greentown well in central northern Indiana at about 3000 feet below sea level.

Perhaps the best evidence we have of the nature of our Ohio Pre-Cambrian materials is in the nature of the known Pre-Cambrian in the north which has been shown to descend as a peneplain beneath the Cambrian and other sediments of these north central states. Everywhere in these northern exposed areas the rocks are crystalline, metamorphosed sediments and tuffs with intrusions and extrusions of granitic and basic material. Our Ohio foundation is known to be Pre-Cambrian, because the Cambrian as unmetamorphosed sediments overlies it everywhere. Hence, in Ohio the rocks which carry this old Pre-Cambrian surface are probably everywhere similar complex crystallines.

Another item suggesting the nature of the materials may be had from the Pre-Cambrian in Canada. Here it is the carrier of several valuable mineral and ore deposits and a large variety of economic materials. The great iron deposits of the Lake Superior region, the copper of the Keweenaw Michigan section, the Sudbury nickel, silver and gold, the cobalt ore, small deposits of gold in a number of places separate from the other metallic ores, asbestos, serpentine marble and a wide variety of good building stones represent both metallic and nonmetallic value in the exposed Pre-Cambrian. Our three or four wells that actually reach Pre-Cambrian in Ohio reach nothing of metallic deposits, but they do reach rock that would be good building stone. The 2000-3000 feet of cover however is sufficient barrier to its economic development.

## PRE-CAMBRIAN STRUCTURES.

The third part of this paper concerns itself with structures of Ohio Pre-Cambrian. A suggestion from the exposed rocks of similar age in our Canadian area is our best lead at present. If, as shown and generally believed, the Pre-Cambrian of the north continues underneath the Paleozoic of Ohio it is reasonable to believe that it carries similarly complex structures. But it is just as true that, from this method of reasoning, we can get no clew as to just what structure is where. The pattern is far too intricate, too confused one pattern with another, to infer safely that because a certain structure occurs near the border of the Paleozoic cover it continues 100 miles beneath that cover.

We really have very little suggestion from our wells concerning structure in these old rocks. Three wells in the Findlay-Tiffin-Woodville triangle found very similar granitic gneiss. One might well infer a mass of granitic gneiss in that locality 30-40 miles across, but one cannot well go farther. The well at Greentown, Howard County, Indiana, some miles north of the capital, is reported passing through a diabase "dike" 20 feet thick in the Keweenaw; but we do not know whether it was pierced at right angles so as to give the exact thickness, or very obliquely so as to make a 20-foot section in a dike only a few feet thick. Diabase dikes may occur in other places.

There are now in use several Geophysical methods of studying covered materials and structures. They are not so well perfected that they tell indisputably what occurs below, but they are well worth considering in the exploration of Ohio Pre-Cambrian. Within the last few years the new Hungarian government through the late director of its Geologic Survey, Dr. Hugo de Boeckh, has made a survey of the covered rocks below the plain and has found what the director considers good evidence of several structures in the ancient rocks below the great unconformity. In a conversation regarding the Ohio situation, he said he felt a survey of western Ohio through 2000-3000 feet of sediments, so well-known as ours now are, would be possible and worth while.

Iron deposits might be located by magnetic methods; certainly no mining should be started unless magnetic methods suggest it. Drilling is always in order. Copper bodies,

metallic and sulphide ores, cobalt and nickel ores may be detected by certain electrical methods in which the potential field is measured. Here again no mining should be started until the geophysical testing suggests it. Our methods are not sufficiently perfected to assure one of actually finding ore bodies even when the measurement of the magnetic and electric properties suggests their presence, because other conditions besides proximity of ore bodies produce differences in potential fields. But study of methods and exploratory surveys are now in order and should be carried on as time and means make possible.

Such ore bodies as the Sudbury and Cobalt in Canada are workable in shafts 2000-3000 feet deep. As the iron ores of the Lake Superior region decline, such bodies as they are at the surface might be worked through a cover of 2000-3000 feet. Probably we could not afford to work an Ohio iron-ore body at such depths *now*, even if we should find one; but no doubt the time will come when we shall be glad to work through the Paleozoic cover for iron, copper, nickel, silver and gold. All of these metals are well known in Pre-Cambrian where it is exposed north of our Paleozoic cover, and may be found in the future under our own Ohio soils.

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#### Respiration in Plants.

This is the title of the latest volume to appear in the Dial Press series of monographs on biological subjects. Messrs. Stiles and Leach attempt to encompass within the covers of this little book a modern, consistent, and condensed treatment of the process of plant respiration. The subject matter is discussed under four chapter headings, to-wit: I. Introductory, II. Respiration of normal plants under aerobic conditions, III. Anaerobic respiration, and IV. The mechanism of respiration. The book is well-rounded, concise, and readable. Perhaps inevitably the authors' evaluation of the subject follows somewhat the temper of their own scientific outlook. Nevertheless, this volume is the only modern treatment of the topic of plant respiration with the exception of Kostychev's well known monograph, which it far excels for the many who prefer to do their reading where the essence of the subject has been distilled out of a mass of otherwise very confusing data. There is a list of the literature cited in the text; this is a short but good working bibliography of the subject. A subject-author index completes the volume. The book deserves a careful reading by every advanced student of botany or biology.—B. S. MEYER.

**Respiration in Plants**, by W. Stiles and W. Leach. 124 pp. New York, The Dial Press, 1932.